

WELCOME, I AM HONORED TO BE HERE AT THE IIR/PDMA CONF.

TO PUT THINGS IN PERSPECTIVE,

I MANAGE THE HARDWARE DEVELOPMENT DIVISION AT THE NASA AMES RESEARCH CENTER IN CALIFORNIA, AND AM AN ADJUNCT PROFESSOR IN THE BUSINESS SCHOOL OF THE GOLDEN GATE UNIVERSITY IN SAN FRANCISCO.

I AM GOING TO PRESENT SOME IDEAS AND THOUGHTS ABOUT MY EXPERIENCES AT NASA BUT WHICH I DO NOT BELIEVE ARE NOT UNIQUE TO NASA.

Zero to Sixty with Design -by- Prototype :

**How to move quickly in product development
by holding off on design**

Four Important Issues:

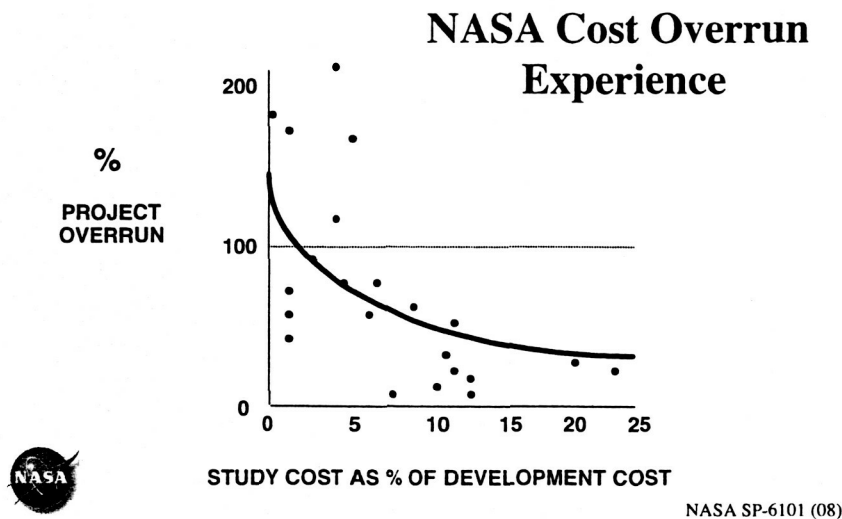
- We start too soon and end too late
- If you don't know where you're going , go there!
- Iteration is not a dirty word, its how we learn
- Experts at fabrication know how to design better



**I'M GOING TO COVER THE FOUR ISSUES SHOWN HERE TO
EMPHASIZE WHY I BELIEVE DESIGN-BY-PROTOTYPE HAS
SIGNIFICANT VALUE.**

LET'S BEGIN WITH, "WE START TOO SOON AND END TOO LATE"

- We start (design) too soon and end (projects) too late



LET ME FIRST TELL YOU WHY I SAY WE START DESIGN TOO SOON AND END OUR PROJECTS TOO LATE - THIS SLIDE SHOWS COST DATA FOR A NUMBER OF PAST NASA PROJECTS

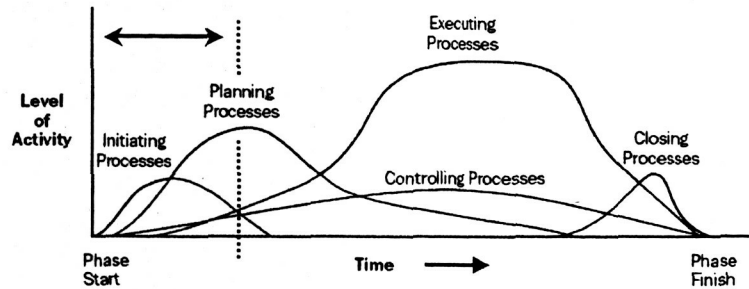
PLOTTED ON THE VERTICAL AXIS IS PROJECT COST OVERRUN, AND, ON THE HORIZONTAL, HOW PROJECT RESOURCES WERE EXPENDED DURING THE EARLY PHASE OF THESE PROJECTS

THE POINT TO TAKE AWAY FROM THIS IS, THAT BY SPENDING AROUND 10% +/- 2% OF THE PROJECT RESOURCES EARLY, TO REALLY UNDERSTAND THE PROJECT, AND TO REDUCE UNCERTAINTY, IN NASA'S EXPERIENCE, WILL KEEP TOTAL PROJECT COSTS WITHIN 100 - 150 % OF THE ORIGINAL ESTIMATE.

IT WON'T GUARANTEE COMING IN ON COST FOR NASA PROJECTS, BECAUSE OF THE COMPLEXITY OF THE PROJECTS THAT NASA UNDERTAKES, AND THE HIGH UNCERTAINTY INVOLVED

LET'S EXAMINE WHY THIS FINDING IS TRUE

PMI Project Development Cycle



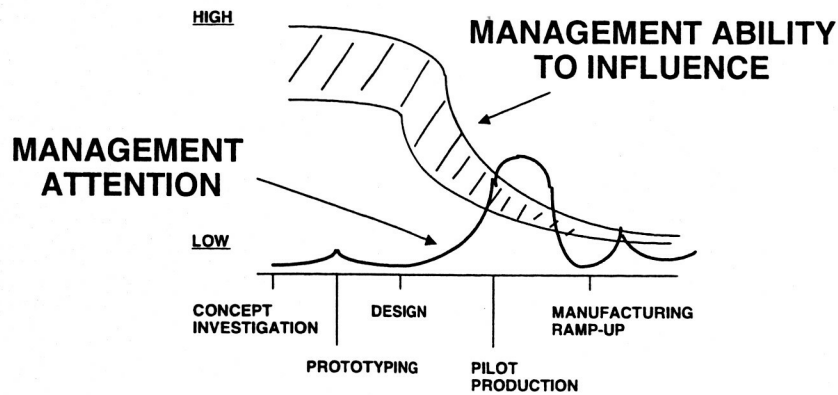
PMI PMBOK Guide

LOOKING AT THE MULTIPLE PROCESSES OF A PROJECT LIFE-CYCLE SHOWN HERE INDICATES HOW THESE PROCESSES INTERRELATE TO EACH OTHER.

USING THE IMPACT OF SUFFICIENT UP-FRONT SPENDING FROM THE NASA SLIDE, MY INTEREST LIES IN THE EARLY PORTION OF THE INITIATING AND PLANNING PROCESSES SHOWN BY THE 2 HEADED ARROW.

THIS EARLY PORTION OF THE PROJECT CYCLE DRIVES THE REST OF THE PROJECT AS SEEN ON THE NEXT SLIDE.

Early Project Development Time Line



Wheelwright & Clark, 1992

THE TIMELINE SHOWN HERE IS THAT EARLY PORTION OF THE PREVIOUS SLIDE AND,

THIS SLIDE SHOWS TWO IMPORTANT THINGS.

1. THE LOWER CURVE SHOWS NORMAL MANAGEMENT INTEREST IN A TYPICAL PROJECT.
2. THE FUNNEL CURVE SHOWS THAT THIS SAME PERIOD IS WHEN MANAGEMENT HAS THE MOST ABILITY TO INFLUENCE A PROJECT. THIS DISPARITY SEEMS LARGELY UNRECOGNIZED BY MANAGEMENT, NOT JUST IN NASA, BUT IN INDUSTRY AND ACADEMIA AS WELL

SUMMARY :

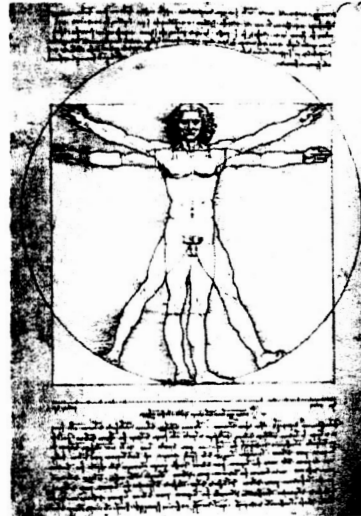
SO, WHAT HAPPENS WHEN A PROJECT IS GIVEN TO ENGINEERING? THEY BEGIN TO DESIGN! INSTEAD OF REDUCING UNCERTAINTY (USING TRIZ, QFD, etc.) AND, BY STARTING DESIGN TOO SOON, THE PROJECT WILL PROBABLY END TOO LATE!

NOW, LET'S MOVE ON TO - IF YOU DON'T KNOW WHERE YOU'RE GOING, GO THERE!

**-If You Don't Know
Where You're Going,
Go There!**



Michelangelo



Leonardo da Vinci

AT FIRST THIS SOUNDS A LITTLE SCARY - ESPECIALLY TO ENGINEERS WHO ASSUME THEY ARE SUPPOSED TO KNOW.

HOWEVER, WHY SHOULD WE, WITH HUNDREDS OF YEARS OF EXPERIENCE CREATING MAN'S GREATEST ACCOMPLISHMENTS, SHY AWAY FROM GOING INTO THE UNKNOWN?

DO YOU SUPPOSE THAT LEONARDO BUILT HIS SCAFFOLDING IN THE SISTINE CHAPEL AND THEN LAYING ON HIS BACK SAID, "I THINK I'LL JUST START PAINTING AND SEE WHERE IT GOES."

I DOUBT IT!

HOW ABOUT da VINCI?

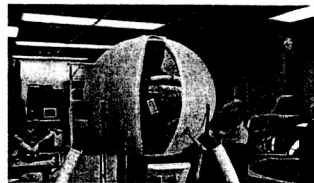
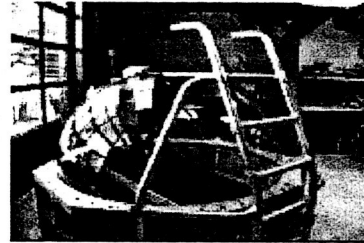
PERHAPS THE GREATEST GENERATOR OF IDEAS EVER, I CANNOT IMAGINE da VINCI SAYING TOO HIMSELF, "THIS IS TOO UNCERTAIN, AND I DON'T THINK I WILL GO THERE"

IF THESE TWO, AND MANY OTHER GREAT MINDS SUCH AS EDISON, AND EINSTEIN DID NOT HESITATE TO PLUNGE INTO THE UNKNOWN, WHY SHOULD WE?

WE SHOULDN'T!

LETS LOOK AT SOME CURRENT EXAMPLES WHERE PEOPLE DIDN'T HESITATE

Positive and Negative, Body-Pressure Devices



IMAGINE FOR A MOMENT, CREATING A DEVICE THAT WOULD REDUCE THE WEIGHT OF A PERSON AFTER SAY KNEE OR HIP SURGERY, OR PERHAPS A BROKEN LEG.

THE NORMAL THERAPY USES A SWIMMING POOL TO REDUCE THE PERSON'S WEIGHT ON THE INJURY BUT THE UNLOADING IS NOT ADJUSTABLE AND CANNOT BE INCREASED OR DECREASED

HOW CAN THIS BE ACCOMPLISHED WITH VARIABLE LOADING?

ONE WAY IS TO CREATE A DEVICE THAT ALLOWS FOR VARIABLE LOADING USING AIR PRESSURE - A BUBBLE IF YOU WILL

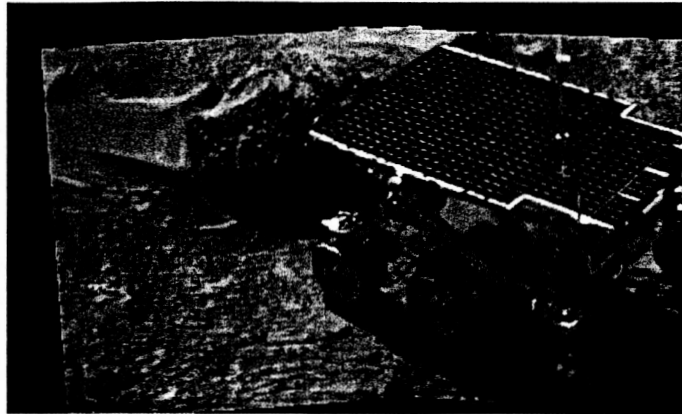
SHOWN HERE IS SUCH A DEVICE THAT, BY PRESURIZING THE BUBBLE, THE PERSON'S WEIGHT ON A TREADMILL CAN BE ADJUSTED FROM NORMAL WEIGHT TO ZERO WEIGHT!

-MOVIE

BUT, WHAT IF YOU WANT TO INCREASE THE WEIGHT ON THE LOWER EXTREMITIES MORE THAN THE WEIGHT OF THE PERSON?

YOU COULD ADD WEIGHTS TO THEM, BUT YOU COULD ALSO PUT THEIR UPPER BODY IN A BUBBLE AND INCREASE THE AIR PRESSURE TO PUSH THEM DOWN ON A TREADMILL AS SHOWN HERE! TWO EXAMPLES OF SIMPLE SOLUTIONS BY "GOING THERE!"

Mars Pathfinder-Rover, Sojourner



NOW, WHO REMEMBERS THIS LITTLE CRITTER? THIS WAS THE FIRST MARS ROVER. THE REASON IT IS IMPORTANT TO THIS DISCUSSION IS THE WAY IT WAS DEVELOPED.

IT BEGAN WITH VAGUE REQUIREMENTS:

- YOU HAVE \$25 MILLION FOR A ROVER TECHNOLOGY DEMONSTRATION PROJECT - WHAT CAN YOU GIVE US FOR THAT?

GOALS: ROVER AROUND - TAKE PICTURES - EXAMINE ROCKS

SUCCESS FACTORS DEFINED: 90% = 1 DAY, 1 PICTURE, 1 ROCK

100% = 7 DAYS, 7 PICTURES, 7 ROCKS

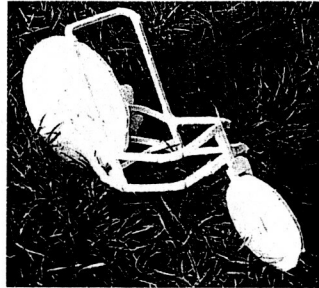
RIGID CONSTRAINTS ON MASS, POWER, & VOLUME

APPROACH: PROJECT WAS SET UP AS A LIVING CELL WITH THE PROJECT MANAGER BEING THE CELL MEMBRANE CONTROLLING EVERYTHING GOING IN AND OUT - MAXIMUM USE OF PROVEN PARTS (MOTOROLA RADIOS)

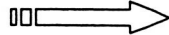
IT WORKED!!!

SUMMARY: IF YOU DON'T KNOW WHERE YOU'RE GOING, GO THERE - BEFORE YOU BEGIN DESIGN!

**- Iteration is Not a Dirty Word,
It's How we Learn!**



from, foamcore model to,



**Recumbent Bicycle for
Disabled Persons**



working prototype

IMAGINE IF YOU WILL, BEING DISABLED WITH THE PROSPECT OF NEVER RIDING A BICYCLE AGAIN.

MY COLLEAGUE HAD JUST SUCH A CHALLENGE FROM THE VETERANS ADMINISTRATION

HE WAS GIVEN THE TASK TO MAKE A BICYCLE FOR DISABLED PEOPLE WHO HAVE LOST THE USE OF THEIR LEGS, OR HAD THEIR LEG(S) AMPUTATED.

WHERE DO YOU BEGIN?

IF YOU DON'T KNOW, BEGIN ITERATING!

- HE BEGAN WITH A FOAM CORE MODEL OF AN INITIAL CONCEPT

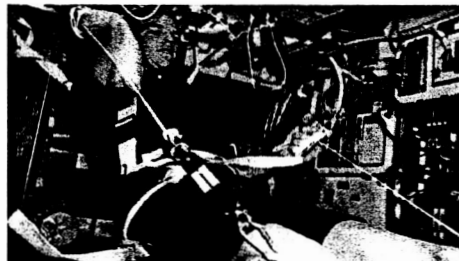
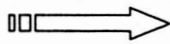
FROM THAT MODEL CAME A WORKING PROTOTYPE SHOWN HERE AFTER MANY ITERATIONS

CAN YOU IMAGINE THE JOY OF SOMEONE WHO CAN ONCE AGAIN TRAVEL A BIKE TRAIL UNDER THEIR OWN POWER?

Simple Exercise Device for Weightless Environments



From, Vomit-Comet to,



Space Shuttle Atlantis

A MORE TYPICAL NASA EXAMPLE IS THE NEED TO EXERCISE DURING THE WEIGHTLESSNESS OF SPACE TO MAINTAIN BOTH BONE AND MUSCLE STRENGTH

TYPICALLY, DEVICES SUCH AS TREADMILLS USED ON EARTH WERE HAULED INTO SPACE AND ASTRONAUTS USED BUNGEE CORDS TO TIE THEMSELVES TO THE PLATFORM SO THEY WOULD EXPERIENCE DOWNWARD TENSION ON THE TREADMILL BELT

HOWEVER, WHAT IF YOU COULD ACCOMPLISH THE SAME THING WITH A SIMPLER DEVICE THAT WORKED JUST AS WELL BUT TOOK UP MUCH LESS ROOM AND WEIGHED A FRACTION OF THE TREADMILL?

AGAIN, A DEVICE MADE FROM ROPES AND SOME RESISTANCE PULLEYS WAS BUILT IN THE LAB AND ITERATED UNTIL IT MET THE REQUIREMENTS FOR BONE AND MUSCLE LOADING

TESTED BY ASTRONAUT SCOTT PARAZYNSKI IN THE NASA 707 AIRCRAFT TO FINE TUNE ITS OPERATION, IT THEN FLEW ON THE SHUTTLE ATLANTIS AND WAS DEMONSTRATED BY SCOTT

- LET'S MOVE ON TO THE CRITICAL FABRICATION ELEMENT OF DESIGN-BY-PROTOTYPE

- Experts at Fabrication Know How to Design Better



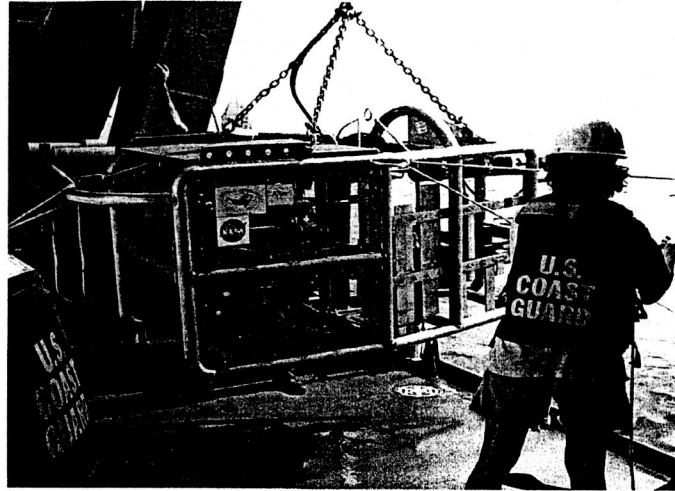
Deep Sea Thermal Vent Viewing System

IN THE PICTURE YOU SEE A TECHNICIAN AND AN ENGINEER WHO APPLIED THE PRINCIPLES OF DESIGN-BY-PROTOTYPE TO A TIME CRITICAL PROJECT.

AN OPPORTUNITY AROSE FOR NASA TO EXAMINE AN UNDERSEA THERMAL VENT FOR LIFE FORMS IN THE SOUTHERN PACIFIC FROM A COAST GUARD SHIP RETURNING FROM ANTARTICA. THE PROBLEM WAS THERE WAS NO AVAILABLE HARDWARE AND THE EQUIPMENT HAD TO BE ON THE SHIP IN 3 WEEKS.

THE ENGINEERING GROUP SPENT A WEEK TRYING TO DETERMINE HOW THEY COULD ACCOMPLISH THIS, AND FINALLY CAME TO US FOR HELP. MY COLLEAGUE, DAN GUNDO ON THE LEFT IN THE PHOTO, BRAINSTORMED WITH THE ENGINEER SOME POSSIBLE WAYS THIS MIGHT BE DONE IN THE TIME FRAME LEFT, AND DECIDED ON A TWO PART SOLUTION - TWO CYLINDERS JOINED BY A FLANGE TO KEEP THEM PARALLEL, ONE CYLINDER WITH A VIDEO CAMERA AND ONE WITH A BATTERY OPERATED LIGHT.

Deployment of Deep Sea Thermal Vent Viewer



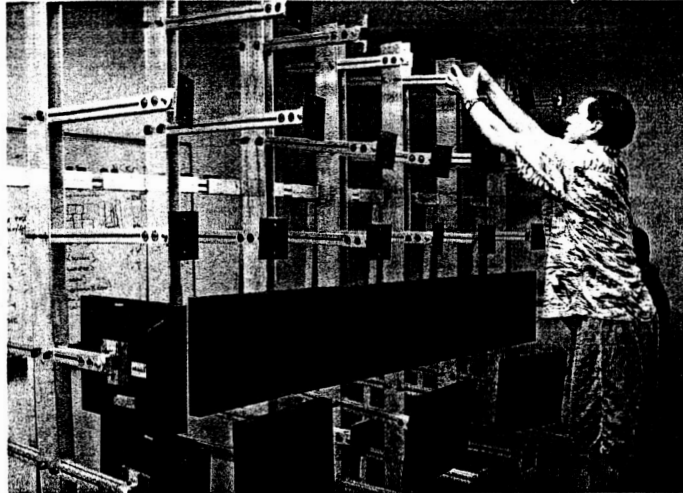
THIS IS THE CAMERA-LIGHT SYSTEM BEING DEPLOYED FROM THE COAST GUARD SHIP - YOU CAN SEE CHARLIE'S FOOT STICKING OUT NEAR THE MIDDLE OF THE FRAMEWORK THAT HELD A NUMBER OF OTHER EXPERIMENTS BESIDES OURS.

NO, CHARLIE DID NOT GO DOWN WITH THE UNIT, BUT HE HAD TO START THE VIDEO CAMERA AND TURN THE LIGHT ON AND THEN PUT THE COVERS ON THE TWO CYLINDERS JUST BEFORE THE EXPERIMENT WENT OVER THE SIDE.

IN THIS EXAMPLE, THE POINT I WANT TO EMPHASIZE IS THE CONCURRENT WAY THE FRONT END OF THE PROJECT WAS APPROACHED - SKETCHES ON PAPER TOWELS SUFFICED FOR DRAWINGS UNTIL THE PROJECT WAS COMPLETED,

EVEN AFTER LOSING A WEEK DUE TO NORMAL ENGINEERING TRYING TO DESIGN THE EQUIPMENT IN THE SIT-DOWN-AT-YOUR-COMPUTER-AND-DRAW-SOMETHING SCENARIO, THE PROJECT WAS COMPLETED IN TIME TO MEET THE TIGHT SCHEDULE AND CAPTURE UNIQUE SCIENCE DATA FOR A VERY SMALL COST

hyperwall Assembly



ANOTHER EXAMPLE IS THE HYPERWALL

THE HYPERWALL PROJECT BEGAN SIMILAR TO MANY PROJECTS WITH THE ONLY REQUIREMENT BEING TO BUILD A FRAME TO HOLD 49 FLAT SCREEN COMPUTER MONITORS IN A 7X7 ARRAY.

LOOKING AT THE TECHNICIAN'S INITIAL SKETCHES, THE RESEARCHERS WANTED TO ADD THE ABILITY TO CURVE THE WALL OF SCREENS BOTH HORIZONTALLY AND VERTICALLY SO A PERSON AT THE CENTER FOCAL POINT WOULD NOT HAVE TO MOVE THEIR HEAD VERY MUCH TO SEE ALL OF THE SCREENS.

WITH THE REQUIREMENTS FINALIZED FOR THAT MODEL, A NEW REQUIREMENT WAS TO BE ABLE TO DISASSEMBLE, CRATE EVERYTHING UP, SHIP IT ACROSS THE COUNTRY, AND THEN REASSEMBLE THE ENTIRE WALL IN 8 HOURS.

THIS SLIDE SHOWS THE INITIAL HYPERWALL ASSEMBLY IN THE LABORATORY.

hyperwall Complete



SHOWN HERE IS THE COMPLETED OPERATING HYPERWALL IN THE LABORATORY WITH THE RESEARCHERS ANALYZING EARTH SATELLITE DATA FOR ANOMALIES AND INTERESTING INFORMATION.

THE DISASSEMBLY, SHIPPING TO THE EAST COAST TO A CONFERENCE, REASSEMBLY, AND OPERATION ALL WENT SMOOTHLY

THE ONLY ENGINEERING INVOLVEMENT IN THIS EXAMPLE WAS TO PRODUCE CAD DRAWINGS OF THE COMPLETED FRAME "AFTER" THE WALL WAS BUILT FOR A TECHNICAL PAPER PRESENTATION

THE TOTAL COST AND TIME INVOLVED TO BUILD THE HYPERWALL WAS A FRACTION OF THE ENGINEERING ESTIMATE JUST FOR THE ENGINEERING DESIGN PORTION

Design-By-Prototype Take-aways

PROBLEM:

Insufficient up front attention when the need and ability to influence technical content, cost, and schedule is greatest.

SOLUTION:

Simple, design-by-prototype reduces unknowns and uncertainty

DESIGN-BY-PROTOTYPE OFFERS THESE ADVANTAGES:

- Improved designs
- Faster development process
- Significant savings potential



WHAT I HAVE SHOWN,

ARE SOME REAL WORLD EXAMPLES WITH THE ATTEMPT TO CONVINCE YOU THAT DESIGN-BY-PROTOTYPE IS AN IMPORTANT CONCEPT TO CONSIDER IN YOUR PRODUCT DEVELOPMENT:

1-THE EARLY PORTION OF A PROJECT IS EXTREMELY IMPORTANT AND SENSITIVE TO DECISIONS MADE EARLY IN DEVELOPMENT

2-DELAYING DETAILED ENGINEERING IS AN IMPORTANT WAY TO EVALUATE IDEAS AND CONCEPTS BEFORE LOCKING IN DESIGN DECISIONS WHEN YOU HAVE LESS THAN COMPLETE INFORMATION

3-MANY PROJECTS, AND MANY PARTS OF OTHER PROJECTS, CAN BE ACCOMPLISHED WITH LITTLE OR NO FROMAL ENGINEERING USING A DESIGN-BY-PROTOTYPE APPROACH

4-THE POTENTIAL FOR SAVINGS IN BOTH RESOURCES AND TIME FAR OUTWEIGHS USING AN INITIAL, SLOWER APPROACH WITH PEOPLE WHO REALLY KNOW HOW TO MAKE THINGS.

AT THE NASA AMES RESEARCH CENTER, WE HAVE COMPLETED MANY NASA RESEARCH PROJECTS USING THIS APPROACH WITH SIGNIFICANT SAVINGS IN BOTH TIME AND COST